Alaska Fisheries Technical Report 52.

ABUNDANCE AND RUN TIMING OF CHINOOK, CHUM, COHO, PINK AND SOCKEYE SALMON IN THE KULUKAK RIVER, TOGIAK NATIONAL WILDLIFE REFUGE, ALASKA, 1994-1996

Mary A. Price
and
Jim Larson

Key Words: Sockeye salmon
Chum salmon
Coho salmon
Chinook salmon
Pink salmon
Counting tower
Kulukak River
Togiak National Wildlife Refuge
Alaska

U.S. Fish and Wildlife Service
King Salmon Fishery Resource Office
P.O. Box 277
King Salmon, Alaska 99613-0277

October 1999

Disclaimer

The mention of trade names or commercial products in this report does not constitute endorsement or recommendation for use by the federal government.

The U.S. Department of Interior prohibits discrimination in programs on the basis of race, color, national origin, religion, sex, age, or disability. If you believe that you have been discriminated against in any program, activity, or facility operated by the U.S. Fish and Wildlife Service or if you desire further information please write to:

U.S. Department of Interior
Office of Equal Opportunity
1849 C Street, NW
Washington, D.C. 20240

The correct citation for this report is:

Price, M. and J. Larson. 1999. Abundance and run timing of chinook, chum, coho, pink, and sockeye salmon in the Kulukak River, Togiak National Wildlife Refuge, Alaska, 1994-1996. U.S. Fish and Wildlife Service, King Salmon Fishery Resource Office, Alaska Fisheries Technical Report 52, King Salmon, Alaska.

Table of Contents

List of Figures

List of Tables

List of Appendices

Alaska Fisheries Technical Report 52.

ABUNDANCE AND RUN TIMING OF CHINOOK, CHUM, COHO, PINK, AND SOCKEYE SALMON IN THE KULUKAK RIVER, TOGIAK NATIONAL WILDLIFE REFUGE, ALASKA, 1994-1996

MARY A. PRICE
AND
JIM LARSON
U.S. Fish and Wildlife Service, King Salmon Fishery Resource Office
P.O. Box 277, King Salmon, Alaska 99613, (907) 246-3442

Abstract.! A counting tower was used to estimate escapement and run timing of five species of salmon into the Kulukak River on Togiak National Wildlife Refuge from 1994-1996. Escapement estimates ranged from 1,032-2,487 for chinook salmon *Oncorhynchus tshawytscha*, 11,970-34,482 for chum salmon *O. keta*, 10,404-13,503 for coho salmon *O. kisutch*, 1,194-12,687 for pink salmon *O. gorbuscha*, and 15,297-16,206 for sockeye salmon *O. nerka*. The chinook, chum, and sockeye salmon runs peaked the first half of July, while pink salmon peaked in late July, and coho salmon peaked in late August to early September. The modal age {freshwater annuli . ocean annuli} was 1.4 for chinook, 0.3 in 1996 and 0.4 in 1994 and 1995 for chum, 2.1 for coho, and 1.3 for sockeye salmon. Compared with the tower escapement estimates for this river, aerial survey escapement estimates were as likely to over estimate as under estimate abundance.

Introduction

The Kulukak River is a relatively small, yet important river for salmon spawning and rearing located on the Togiak National Wildlife Refuge (Refuge). Five Pacific salmon species spawn in the river including chinook *Oncorhynchus tshawytscha*, chum *O. keta*, coho *O. kisutch*, pink *O. gorbuscha*, and sockeye *O. nerka* salmon. Beyond the ecological importance of salmon to the river system, the resource supports subsistence and sport fisheries in the river and commercial fisheries in the saltwater.

Salmon bound for the Kulukak River are harvested primarily in the Kulukak commercial salmon management district. The commercial fishery is managed by the Alaska Department of Fish and Game (Department) to achieve escapement objectives of 16,000 sockeye and 1,000 chinook salmon into the Kulukak River as determined by aerial surveys. Aerial surveys have been conducted by the Department since 1977. Commercial fishing occurs on a three-day-per-week fishing schedule and is adjusted by emergency order based on commercial catch success and in-season aerial surveys. In 1995, 100,849 salmon were harvested in the district (Alaska Department of Fish and Game 1996). Sockeye salmon comprised the largest catch at 76,503 fish followed by 23,121 chum, 1,183 chinook, 41 pink, and 1 coho. Because many of the salmon caught in the Kulukak district are fish migrating to the Togiak River, the harvest of Kulukak River fish cannot be determined.

The Refuge permits two commercial sport guides to operate on the Kulukak River. These guide operations primarily fly clients to the river each day and target chinook and coho salmon. In 1994, 308 guided anglers caught 209 chinook and harvested 87. In the same year, these anglers caught 2587 coho and harvested 636. Access for unguided anglers is unrestricted but use appears to be low. No catch or harvest data are available for this segment of the angling public.

The Public Use Management Plan (U.S. Fish and Wildlife Service 1991) summarized the subsistence pattern for use for the Kulukak area. Subsistence use is focused on the area during the herring fishery in April and May and does not appear to receive much use during the salmon migration. Since the village of Kulukak was abandoned, the Kulukak River does not seem as important for subsistence salmon harvest as when the village was inhabited.

The Alaska National Interest Lands Conservation Act mandates that salmon populations and their habitats be conserved within the Refuge and subsistence opportunities for local residents be provided (U. S. Fish and Wildlife Service 1990). The goal of this study is to expand our understanding of the salmon runs in this system. Beginning in 1994, the Service initiated a three-year study in the Kulukak River to: (1) to estimate escapement and run timing of chinook, sockeye, chum, pink, and coho salmon; (2) estimate age, length, and sex compositions of chinook, sockeye, chum, and coho salmon returns; and (3) compare tower counts with aerial survey results.

Study Area

The Kulukak River, located in southwestern Alaska, drains into the Bristol Bay (Figure 1). The regional climate is moderate, polar maritime, characterized by protracted cloud cover and frequent precipitation. Air temperatures in the area range from an average summer maximum of 18°C to an average winter minimum of -16°C. Total precipitation averages about 63 cm. Annual snowfall averages 152 to 178 cm along the coast, but may exceed 381 cm in the mountains.

The Kulukak River originates at an approximate elevation of 305 m at the head of a long valley between the Igushik and Ungalikthluk River drainages. The river flows south for approximately 61 km before emptying into Kulukak Bay. The lower 8 km of river channel banks are steep sided, undercut, and vegetated with grass, willows, and alders. In this lower section the width varies from 25-45m, and the substrate is composed of fine gravel and silt. The upper river is shallow with gravel substrate and varies in width from 15-40 m. Starting about 15 km up from the mouth, the river meanders between non vegetated vertical bluffs. The Kulukak valley is characterized by tundra ridges with willow scrub and alder brush in the riparian zone. There are several small stands of cottonwood trees in the upper valley. River bottom composition is primarily fine to medium gravel with some areas of cobble. Numerous meanders in the river have created small runs and eddies with occasional deep water pools (U. S. Fish and Wildlife Service 1990, U. S. Fish and Wildlife Service 1991) .

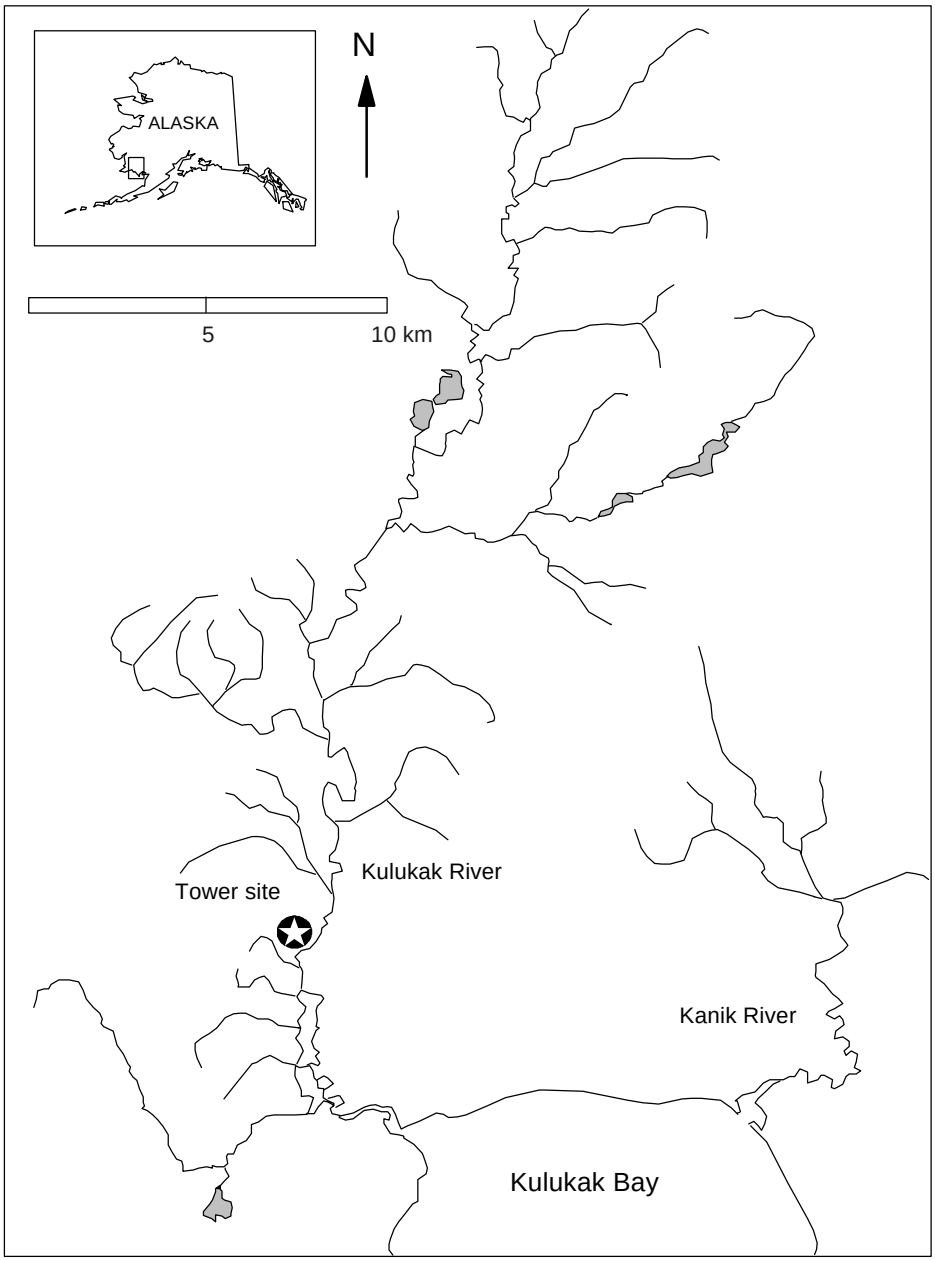

Figure 1. Location of the counting tower on the Kulukak River, Togiak National Wildlife Refuge, Alaska, 1994-1996.

Methods

Escapement and Run Timing

The Kulukak River tower site was located 12.5 km upstream from the mouth (Figure 1). Counts were made from a 6-m high bluff on the West bank and a 7.5-m tall construction scaffold (counting tower) on the East bank. A three-to four-person crew conducted the counts from mid-June to the end of July in 1994 and to early-September in 1995 and 1996. A 4-foot wide, light-colored plastic mesh fence (flash panel) was anchored flat across the river bottom to provide a contrasting background for optimal fish identification. Polaroid sunglasses were worn by the crew to minimize glare off the water surface. Artificial lights were used to obtain counts during hours of darkness.

Enumeration sampling followed the protocol established by the Department's Commercial Fisheries Management and Development Division (Alaska Department of Fish and Game 1984). Counting towers using similar methods have been used in the Bristol Bay area for several decades (Becker 1962, Seibel 1967). This method provides salmon passage estimates which were derived by expanding 10-minute counts of individual fish made every hour of the calendar day for each bank of the river. The 10-minute counts were multiplied by an expansion factor of six to calculate the hourly estimate. The 24 estimates from both banks were summed to provide the daily passage estimates.

When the systematic counts were interrupted, the escapement was calculated as the mean of the hourly estimates of the previous and subsequent days for the missing period. For example, if counts were suspended from 1000-1600 hours on Wednesday, then the counts for 1000-1600 hours for Tuesday and Thursday were averaged and used as Wednesday's estimate. Counts were suspended for the following reasons: (1) periods of high, turbid water; (2) when all personnel were needed during biological sampling sessions; and (3) to provide crews with time off.

Data from the salmon counting tower, adjusted for hours of missing counts, are summarized and tabulated for this report. Escapement estimates are graphically displayed by species and by year. The seasonal estimates from the tower are compared to the peak aerial surveys conducted by the Department and the Refuge (Weiland et al. 1994; Brookover et al. 1995; Regnart et al. 1996).

Age, Sex, and Length Data

A beach seine (30.5m long, 3.1m deep, and 7.6cm stretch mesh) was the primary gear used to capture salmon for sampling. Seining was conducted three to five times per week throughout the season with a goal of 160 fish per species per week. Hook and line gear was used to supplement the chinook and coho salmon samples. Biological information was entered on Alaska Department of Fish and Game Commercial Fisheries Division adult salmon age-sex-length mark-sense forms (version 2.1). Length was measured from mid-eye to fork-of-caudal-fin and rounded to the nearest 5 mm. Sex was determined by observing external characteristics. Scales for age analysis were

collected from sockeye, chum, chinook, and coho salmon. Scale samples were taken from the area 3-4 rows above the lateral line on a diagonal between the insertion of the dorsal fin and the origin of the anal fin. One scale was collected from each sockeye and chum salmon. Three scales were collected from each chinook and coho salmon. Scales were mounted on gum cards and later scale impressions were made onto clear acetate cards. Ages were then interpreted from the impressions by research biologists with the Commercial Fisheries Management and Development Division in Anchorage. Age designations are expressed in the European fashion (Koo 1962) where numerals preceding the decimal denote freshwater annuli, and numerals following the decimal refer to the marine annuli.

Age, length, and sex composition of sockeye, chum, chinook and coho salmon are summarized in tables. Mean lengths of males and females by age were compared using a two-tailed *t*-test at $\alpha = 0.05$ (Zar 1984).

Comparison of Tower and Aerial Survey Escapement Estimates

The annual tower escapement estimate was compared to the adjusted peak aerial escapement estimate by species. Although several aerial surveys are conducted each year, the peak survey count is adjusted by a correction factor and becomes the annual escapement estimate. We limited our comparison to the annual escapement number and focused on the accuracy of the aerial estimate when compared to the tower estimates.

Results

Escapement and Run Timing

Project Season.-The Kulukak Tower was set up in late-June of each year. In 1994, the project was operated through the sockeye salmon run and ended July 31. In 1995 and 1996, the season was extended into mid-September to count through the majority of the coho salmon run (Appendix 1).

Missed Tower Counts.-On average, the counting crew conducted 88% of all possible hourly counts for the three years of the project. Of the 12% missed counts, 8% were scheduled breaks from 0800-1500 hours, inclusive. These hours were selected because the salmon passage was typically low. For example, sockeye salmon passage rates were calculated using data from days with no missing counts. Throughout an average 24-hour day, sockeye salmon passage rates were lowest from 0800-1500 hours (11%), in contrast to passage rates of 37% from 2400-0700 hours, and 52% from 1600-2300 hours.

From June to late-July (during the sockeye salmon run), the crew conducted 92% of all possible hourly counts. Of the 8% missed counts, 5% were scheduled breaks during the hours of low salmon passage from 0800-1500 hours, inclusive.

Sockeye salmon.-The magnitude of the sockeye salmon run was the least variable of all the Kulukak River salmon for the three years counts were conducted (Figure 2). The earliest that sockeye salmon were observed was June 19, 1995, and 95% had passed the counting station by July 31. Seasonal counts ranged from 15,297 in 1994 to 16,206 in 1996 (Appendix 1). In 1994, the peak of the run occurred during the week beginning July 9. In 1995 and 1996, the peak was more protracted, but most fish passed the counting station during the week beginning July 2 (Figure 3).

Chinook salmon.-Chinook salmon were the least abundant salmon species in the Kulukak River. The seasonal counts ranged from 1,032 in 1996 to 2,487 in 1995 (Appendix 1). The earliest that chinook salmon were observed was June 21, 1995, and 94% had passed the counting station by July 31. In 1994 and 1995, the peak of the run occurred during the week beginning July 16. In 1996, the peak occurred one week later, during the week beginning July 23 (Figure 3).

Chum salmon.-Chum salmon escapement varied by a large magnitude among the sample years (Figure 2). The seasonal counts ranged from 11,970 in 1994 to 34,482 in 1996 (Appendix 1). The earliest that chum salmon were observed was June 22, 1995, and 91% had passed the counting station by July 31. In 1994, the peak of the run occurred during the week beginning July 23. In 1995, the peak occurred one week earlier, during the week beginning July 16. In 1996, large numbers of chum salmon were observed as early as the week of July 2, and numbers remained high through the week of July 16. The peak was bimodal for the weeks of July 2 and 16 (Figure 3).

Pink salmon.-Pink salmon escapement varied by a large magnitude among the sample years (Figure 2). The seasonal counts ranged from 1,194 in 1995 to 12,687 in 1994 (Appendix 1). The earliest that pink salmon were observed was June 26, 1996. The pink salmon run tended to be protracted and continue into September. In 1994 and 1996, the peak of the run occurred during the week beginning July 23. The weak year for the pink salmon run was 1995, but there was a small escapement which peaked during the weeks beginning July 16 and 23 (Figure 3).

Coho salmon.-The seasonal counts for coho salmon were 13,503 in 1995 and 10,404 in 1996 (Appendix 1). The earliest that coho salmon were observed was July 26. In 1995, the peak of the run occurred during the week beginning September 3. In 1996, the peak occurred during the week beginning August 27 (Figure 3).

Age, Sex, and Length Data

Sockeye salmon.-Ten age groups were identified from a total of 944 sockeye salmon sampled from 1994 to 1996 (Appendix 2). This total includes only those samples for which a scale age could be determined. Three age groups (1.1, 0.4, 3.3) had fewer than five samples each and can be considered rare. Most sockeye salmon (65%) were aged 1.3, followed by age 0.3 fish (16%). Females made up 57% of sampled sockeye salmon in 1994 and 1995, and 47% in 1996. For all

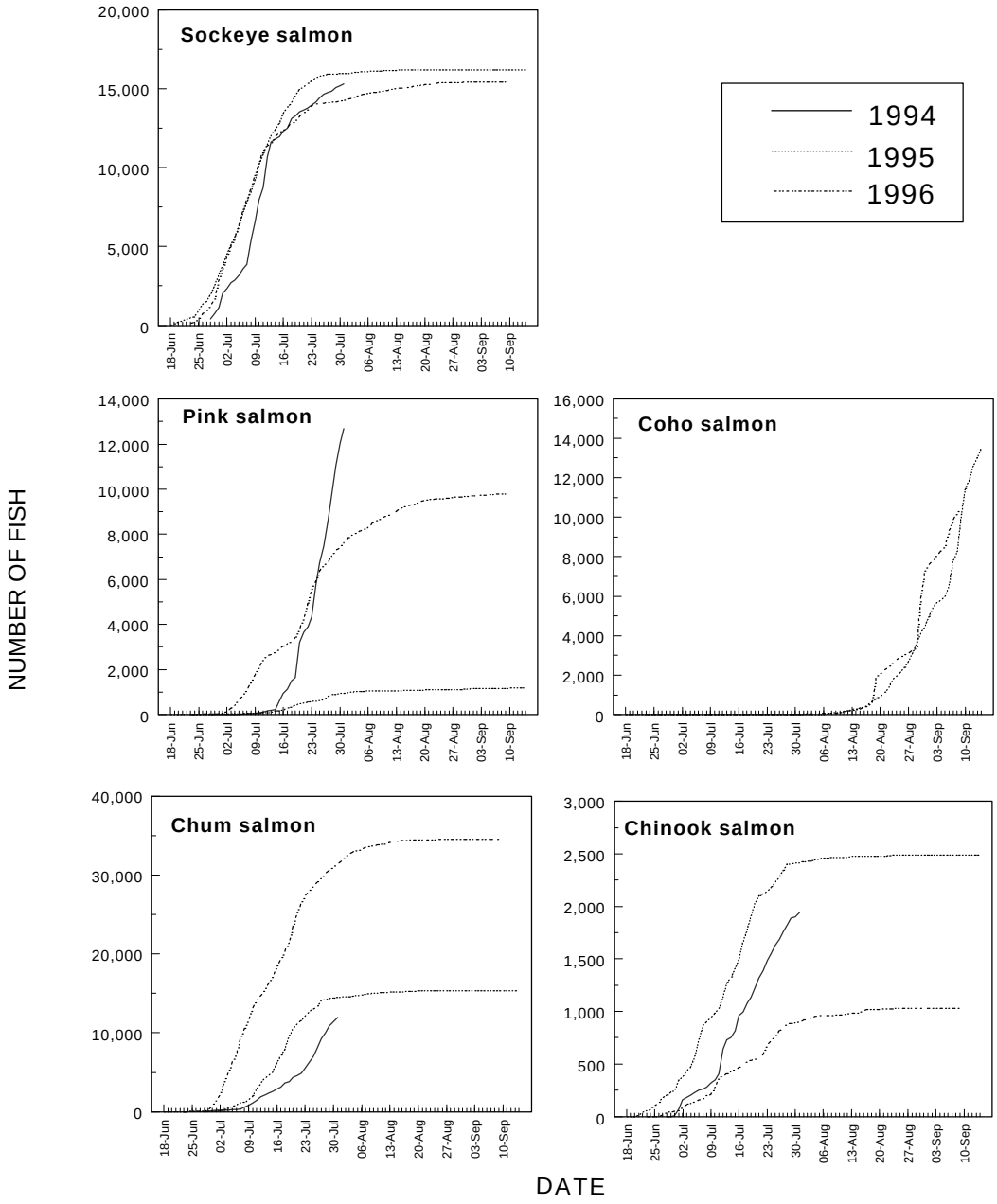

Figure 2. Cumulative daily salmon escapement estimates for the Kulukak River tower, 1994-1996.

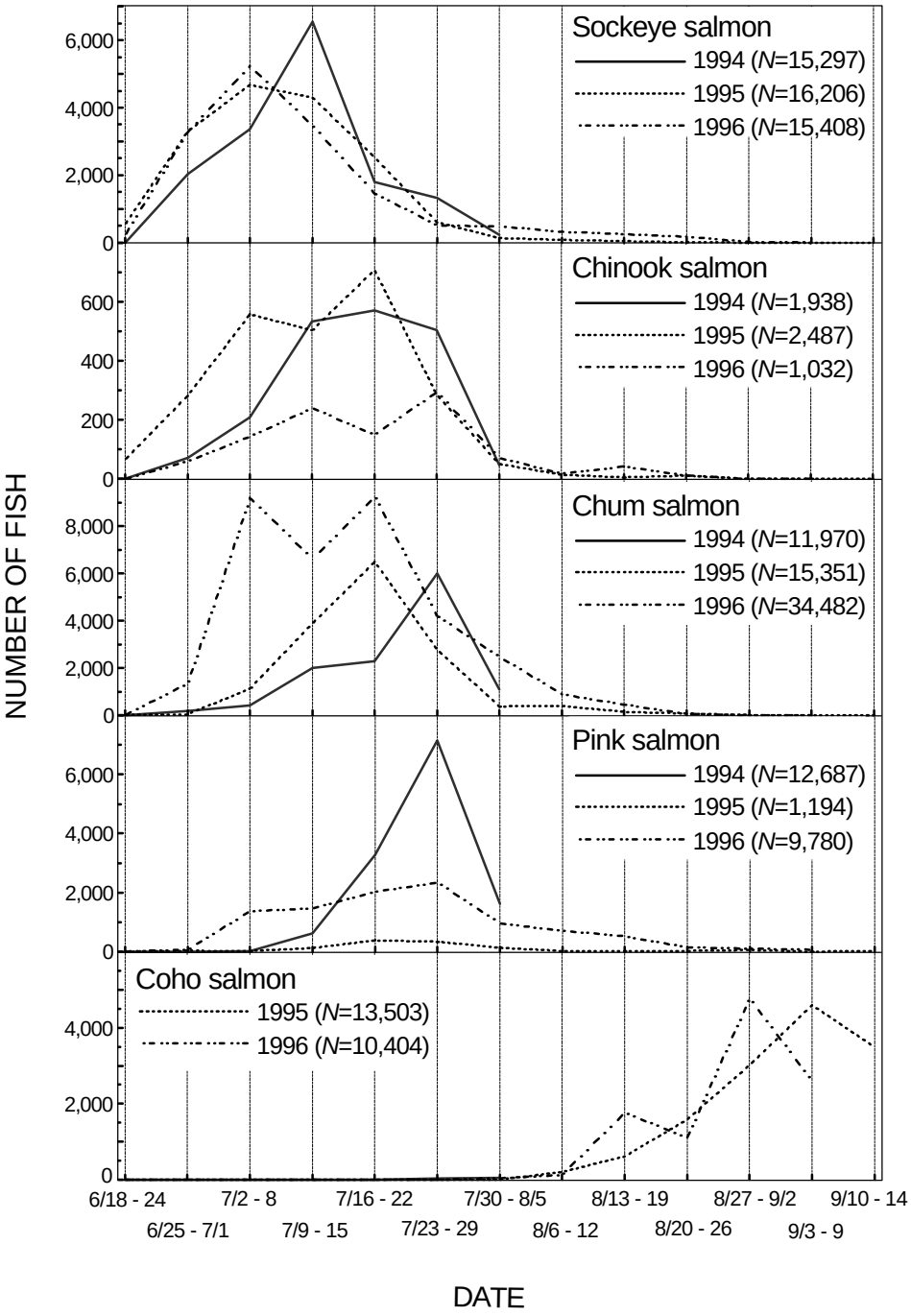

Figure 3. Weekly salmon escapement estimates for the Kulukak River tower, 1994-1996.

years combined, 53% of the sample was female (Table 1). The mean length of sampled males was significantly greater (P>0.05) than females for all age groups combined, and in corresponding age groups (Appendix 6).

Chinook salmon.-Six age groups were identified from a total of 68 chinook salmon sampled from 1995 to 1996 (Appendix 3). This total includes only those samples for which a scale age could be determined. The modal age (44%) for chinook salmon was age 1.4. Females made up 53% of sampled chinook salmon in 1995, and 54% in 1996 (Table 1). The mean lengths of male and female chinook were significantly different (P>0.05) from each other, but there was no consistent result in which sex had the greater length (Appendix 6).

Chum salmon.-Four age groups were identified from a total of 1,362 chum salmon sampled from 1994 to 1996 (Appendix 4). This total includes only those samples for which a scale age could be determined. Age 0.2 fish were only observed during 1995, numbered only 12 individuals, and can be considered uncommon. In 1994 and 1995, 55% of chum salmon were aged 0.4. The modal age shifted in 1996, when 78% of the chum salmon were aged 0.3. For all years combined, most chum salmon (53%) were aged 0.3, followed by age 0.4 fish (39%). Females made up 53%, 40%, and 33% of sampled chum salmon in 1994, 1995, and 1996, respectively. For all years combined, 40% of the sample was female (Table 1). The mean length of sampled males was greater than females (P>0.05) for all age groups combined, and in corresponding age groups (Appendix 6).

Coho salmon.-Three age groups were identified from a total of 581 coho salmon sampled from 1994 to 1996 (Appendix 5). This total includes only those samples for which a scale age could be determined. Most coho salmon (77%) were aged 2.1, followed by age 1.1 fish (20%). Females made up 51% of sampled coho salmon in 1995 and 50% in 1996 (Table 1). For age 2.1 and 3.1 fish, there was no statistical difference between the mean lengths of sampled males and females (P<0.05) (Appendix 6).

Comparison of Tower Data with Aerial Surveys

No clear pattern developed when seasonal tower estimates were compared with the data from aerial surveys (Table 2). Five of the aerial survey estimates were greater than the tower estimates while six aerial survey estimates were less than the tower estimates. The difference between the estimates was highly variable and ranged from 8 to 300%. Coho salmon estimates had the poorest correlation.

Table 1. Sex composition of salmon collected by beach seine and hook and line gear in the Kulukak River, 1994-1996.

Species	Year	Percent Male	Percent Female	Species	Year	Percent Male	Percent Female
Sockeye	1994	43	57	Chum	1994	47	53
	1995	43	57		1995	60	40
	1996	53	47		1996	67	33
	ALL	47	53		ALL	60	40
Chinook	1995	47	53	Coho	1995	49	51
	1996	46	54		1996	50	50
	ALL	47	53		ALL	50	50

Table 2. Comparison of tower and aerial survey salmon escapement estimates for the Kulukak River, 1994-1996.

	1994			1995			1996		
		Aerial Survey[a]			Aerial Survey[a]			Aerial Survey[a]	
Species	Tower	Estimate	Peak	Tower	Estimate	Peak	Tower	Estimate	Peak
Sockeye	15,297	20,540	10,270	16,206	6,000	3,000	15,408	4,980	2,490
Chinook	1,938	2,088	835	2,487	1,075	430	1,032[b]	1,745	698[c]
Chum	11,970	32,100	10,700	15,351	7,600	3,800	34,482	15,120	7,560
Coho	---	---	---	13,503	3,555	1,185	10,404	30,870	10,290

[a] Weiland et al. 1994; Brookover et al. 1995; Regnart et al. 1996. "Peak" refers to the aerial survey with the highest count, and "Estimate" is calculated by multiplying the peak count with a correction factor.

[b] US Fish and Wildlife Service survey

[c] US Fish and Wildlife Service survey conducted past peak

Discussion

Escapement and Run Timing

The Kulukak River presented unusual conditions for a salmon counting tower. Traditionally, counting towers are used on large drainages with high escapement numbers and low species diversity (sockeye salmon usually predominate). The Kulukak, by contrast, is a relatively small drainage with relatively low escapement numbers of five salmon species. Overall, we felt the tower yield good estimates of salmon escapement. However, the following problems affected the accuracy of the estimates: (1) the ability to differentiate salmon species from the tower; (2) the influence of weather conditions on viewing quality; (3) the interaction between the salmon and the flash panel; (4) the interaction between the salmon and the night lights; (5) the tower location; and (6) coho salmon run timing. Another concern was the lack of a left bank tower during the first year of the project. These are discussed below.

The Kulukak River had a width of 40 m, and a maximum depth of 1.5 m at the counting site during average summer low flow. Because of the river's small size, no tower was taken to the site during the first year of the project, and counts were conducted from a bluff on the West bank. Under good viewing conditions, one tower worked well. When glare and wind chop obscured vision, accurate counts were difficult. Additionally, the artificial lights used at night were not powerful enough to reach the far bank. Therefore, a scaffolding tower was erected on the East bank and counts from both banks began on July 28, 1994. When counts were restricted to the West bluff, fish could have passed undetected at night, and species identification was more difficult for fish swimming on the far bank. Therefore, escapement estimates from this year should be interpreted conservatively.

Because the Kulukak River is a mixed species drainage, there was concern about proper identification of fish from the tower. Particularly, sockeye and chum salmon can be easily confused with each other when they are fresh from the ocean. However, on the Kulukak River, these two species were easy to distinguish, because sockeye salmon passing the tower from June to mid-July were predominantly bright, or silvery in coloration. In contrast, chum salmon were watermarked by the time they reached the tower site. Only a couple bright chum salmon were seen during the whole season in the beach seine hauls, where fish could be inspected closely for proper identification. This trend was consistent for all three years of sampling. Therefore, we concluded that sockeye and chum salmon could be easily differentiated from each other except during poor visibility conditions.

Chinook generally did not present an identification problem because of their size. However, jack chinook had the potential to be confused with sockeye salmon. Early in the season, chinook were silvery in appearance. However, this was not considered a significant problem because (1) even in their silvery states, sockeye and chinook salmon had different body and tail coloration; (2) chinook salmon tended to favor the center of the channel, whereas sockeye salmon favored the banks; (3) fish passage rates at the tower were generally low, allowing each individual fish to be examined for species identification characteristics; and (4) the magnitude of the chinook

escapement was small compared to the sockeye salmon escapement, so isolated cases of misidentification would have little effect on the overall escapement estimates.

Pink salmon were generally watermarked by the time they passed the tower. Their coloration, body size, and body shape made them distinctive from the tower. The escapement estimate for pink salmon in 1994 was probably conservative since 1994 was a short counting season. True escapement was probably higher.

In recent years, the Department extended some of their tower operations to monitor coho salmon returns (Brookover and Brannian 1995, Russell 1996), and they documented that early-run coho salmon were easily confused with late-run bright sockeye salmon. In the Kulukak River, however, the confusion was minimal, because there was very little overlap between sockeye and coho salmon returns (Figure 2). In addition, there were very few bright sockeye salmon in the Kulukak River after July.

In general, salmon species were easy to identify under good viewing conditions, even at night. Differentiating between species became more difficult with various surface disturbances such as glare, wind chop, and heavy rain. An experienced crew could mitigate this visual degradation using other cues such as fish body size, swimming behavior, position within the river channel, and time of day (diurnal patterns).

An essential tool used to aid species identification was the flash panel. This facilitated in spotting and identifying fish in several ways: (1) The light color provided contrast to make the fish more visible from the tower; (2) the four-foot wide panel aided tower personnel in estimating length of fish, a factor of fish identification; and (3) the panel provided a visual anchor for starting and stopping escapement counts. This flash panel was essential in identifying fish species under moderate to poor viewing conditions, when fish would otherwise blend into the natural substrate.

The flash panel affected fish behavior. Salmon sometimes paused before crossing the panel, then darted across, making precise counts difficult. The mesh also modified the river's flow. A slight eddy current developed behind the panel causing one or two salmon would hold along the downstream edge of the mesh. Overall, the advantages of the flash panel outweighed the disadvantages.

The night lights were another necessary tool for counting salmon, but they affected fish behavior. Salmon tended to hold downstream of the lights, or swim quickly and erratically through the illuminated area. Different lighting intensities and angles were tried, but any configuration that provided enough lighting for counting also spooked the salmon. The magnitude of error is unknown for night counts. Night operations may undercount salmon, but provide at least a minimum count for hours of darkness.

As an experiment, we attempted to use night vision goggles to count fish at night. We illuminated the water using a car headlight with an infrared filter from shore. Surface glare from ambient and infrared light was a major problem. We suspended the light above the water and redirected the beam perpendicular to the water surface. This illuminated a small area approximately 2m in diameter without causing surface glare and we were able to easily observe and identify salmon. The infrared light did not seem to affect fish behavior. While the surface

lighting could be adjusted, we concluded that an underwater lighting system of infrared or low-level white light could overcome the problems of surface lighting and possibly improve night counting. Further experimentation using night vision goggles is warranted.

The tower location affected escapement counts for some species. The estimate of chum and pink salmon run size should be considered a minimum since some fish spawned below the tower site. Moving the tower site down river could reduce this problem but conflicts with the sport fishery would probably develop.

The run timing of coho salmon affected the accuracy of their escapement estimate. Coho salmon were migrating past the tower site after operations were discontinued. The tower could be operated later in the season but water conditions and flooding will always make counting coho salmon difficult.

Age, Sex, and Length Data

Beach seine and hook and line samples provided data to estimate age, length, and sex compositions of chinook, sockeye, chum, and coho salmon. These data provide baseline information to observe changes in the population characteristics. Seining efforts yielded sufficient samples sizes of sockeye and chum salmon. Chinook and coho salmon were more difficult to seine because of their low numbers or behavior. Therefore, coho and chinook caught on hook and line were added to the seine numbers to increase the sample size.

Comparison of Tower Data with Aerial Surveys

Because of the relatively small run in the Kulukak River, Department and Refuge biologists monitor escapement using aerial surveys. Several surveys are flown each year depending on weather and funding. Escapement estimates are made by multiplying the peak aerial count with an expansion factor. Typically, the expansion factor is two but will vary by water conditions and species. The adjustment is based on biologists best judgement. In general, when aerial surveys are compared to other escapement methods, aerial estimates are not accurate or precise. The variability is linked to the spotters experience and viewing conditions. Indeed, when aerial surveys were compared to tower estimates on the Kulukak River, similar results are found. With three years of tower escapement estimates, aerial surveys were found as likely to over as under estimate salmon abundance, irrespective of species. Since a consistent bias was not evident, we cannot recommend any improvements over the existing correction factors.

Comparison of coho salmon tower and aerial survey estimates had the weakest correlation. Coho salmon aerial surveys are usually conducted after the fall rains begin resulting in poor viewing conditions which probably explains the difference between counts. Although, of the five salmon species counted past the tower, coho salmon estimates were least accurate since fish were still migrating past the tower site when tower operations were discontinued.

With the salmon run sizes and available funding, a labor intensive, costly tower or weir operation doesn't appear to be cost effective or a long term option to monitor escapement. We suggest continuing the aerial surveys and setting a floor count for all species. If the count drops below the floor for several years, then additional management actions may be warranted.

Our greatest concern is the chinook salmon escapement. In 1996, chinook salmon escapement approached the Departments minimum escapement goal of 1000 fish. The corresponding aerial survey count was 500 chinook salmon. We feel this is a minimum number to maintain the population and meet the needs of the Refuge. If the peak aerial count continues to fall below 500 fish, then we feel management action is needed. The other populations appear sustainable at current escapement levels.

Acknowledgments

Special appreciation is extended to the many people who contributed to this project. First, my thanks to all those who served on the critical job as tower staff: Rob Baer, Patti Clinton, Ward Degner, Tom Farb, Blair Flannery, Mike Hoskins, Tim Lynch, Matt Nemeth, Natalie Raethke, Sean Stash, Trip Stringer, Eva Strothotte, and Brian Thomas.

I also appreciate the technical assistance and aerial surveys provided by our Alaska Department of Fish and Game partners: Tom Brookover and Jim Browning (Division of Commercial Fisheries Management and Development, Dillingham Office). A special thanks goes to Jim Menard (Division of Commercial Fisheries Management and Development, Anchorage Office) for aging all the Kulukak River salmon scales.

We appreciate the loan of the night vision goggles by Mike Atwood of Aviation Specialties ULTD, Idaho Falls, ID.

Much thanks to all the U. S. Fish and Wildlife staff who provided many support functions: Gary Terry for all his maintenance support, which included equipment manufacture and repair, and plenty of maintenance consulting over the radio; Teri Metcalf for her logistical support; Steve Klosiewski for his statistical support; and to all the folks at the Togiak National Wildlife Refuge who provided assistance.

Finally, I thank Bud Hodson and Bill Martin for their generosity in sharing their expert local knowledge about the Kulukak River and it’s fisheries.

References

Alaska Department of Fish and Game. 1984. Division of Commercial Fisheries. Escapement enumeration tower operational plan, 1984. Dillingham, AK.

Alaska Department of Fish and Game. 1996. Bristol Bay Annual Management Report for 1995. Division of Commercial Fisheries Management and Development, Regional Information Report No. 2A96-06, Anchorage, AK.

Becker, C.D. 1962. Estimating red salmon escapements by sample counts from observation towers. U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Washington. Fishery Bulletin 192, Volume 61.

Brookover, T.E. and L.K. Brannian. 1995. Wood River Coho Salmon Enumeration, 1994. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 2A95-02, Anchorage.

Brookover, T.E. ,J.B. Browning, J.R. Regnart, R.B. Russell and K.A. Weiland. 1996. Salmon spawning ground surveys in the Bristol Bay Area, 1995. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 2A96-031, Anchorage.

Koo, T.S.Y. 1962. Age designation in salmon. Pages 301-324 in T.S.Y. Koo, editor. Studies of Alaska red salmon. University of Washington Press, Seattle, WA.

Regnart, J.R., K.A. Weiland, T.E. Brookover and J.B. Browning. In press. 1996. Salmon spawning ground surveys in the Bristol Bay Area, 1996. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division. Anchorage.

Russell, R.B. 1996. Coho Salmon Escapement Counts in the Egegik District, Bristol Bay, Alaska, 1995. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 2A96-04, Anchorage.

Seibel, M.C. 1967. The use of expanded ten-minute counts as estimates of hourly salmon migration past the counting towers in Alaskan rivers. Alaska Department of Fish and Game, Division of Commercial Fisheries, Informational Leaflet 101, Juneau.

U.S. Fish and Wildlife Service. 1990. Togiak National Wildlife Refuge Fishery Management Plan. Togiak National Wildlife Refuge, Dillingham, AK.

U.S. Fish and Wildlife Service. 1991. Togiak National Wildlife Refuge Public Use Management Plan. Togiak National Wildlife Refuge, Dillingham, AK.

Weiland, K.A., R.B. Russell, J.R. Regnart and T.E Brookover. 1994. Salmon spawning ground surveys in the Bristol Bay Area, 1994. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report No. 2A94-034, Anchorage.

Zar, J.H. 1984. Biostatistical analysis, second edition. Prentice and Hall, Englewood Cliffs, New Jersey.

Appendix 1A. Daily salmon counts from the Kulukak River tower,1994.[d]

Date		1994 Daily Counts					1994 Cumulative Counts				
		Sockeye	Chinook	Chum	Pink	Coho	Sockeye	Chinook	Chum	Pink	Coho
June	28	402	0	12	0	0	402	0	12	0	0
	29	342	0	18	0	0	744	0	30	0	0
	30 *a*	396	12	78	0	0	1140	12	108	0	0
July	1	888	60	66	0	0	2028	72	174	0	0
	2	300	84	24	0	0	2328	156	198	0	0
	3	384	24	6	0	0	2712	180	204	0	0
	4	168	24	24	0	0	2880	204	228	0	0
	5 *c*	276	24	15	0	0	3156	228	243	0	0
	6	432	24	30	18	0	3588	252	273	18	0
	7	288	12	114	0	0	3876	264	387	18	0
	8	1512	18	192	6	0	5388	282	579	24	0
	9 *a*	1242	36	222	30	0	6630	318	801	54	0
	10	1302	30	318	36	0	7932	348	1119	90	0
	11	804	60	324	18	0	8736	408	1443	108	0
	12 *a*	1974	234	420	54	0	10710	642	1863	162	0
	13 *a*	894	90	234	42	0	11604	732	2097	204	0
	14	204	18	294	24	0	11808	750	2391	228	0
	15	138	66	192	408	0	11946	816	2583	636	0
	16	384	144	276	306	0	12330	960	2859	942	0
	17	168	36	258	186	0	12498	996	3117	1128	0
	18	630	84	564	378	0	13128	1080	3681	1506	0
	19	144	54	150	150	0	13272	1134	3831	1656	0
	20	270	96	486	1548	0	13542	1230	4317	3204	0
	21	96	90	288	444	0	13638	1320	4605	3648	0
	22	114	66	258	264	0	13752	1386	4863	3912	0
	23	204	102	666	426	0	13956	1488	5529	4338	0
	24	198	60	732	1410	0	14154	1548	6261	5748	0
	25	258	84	798	966	0	14412	1632	7059	6714	0
	26	234	54	990	768	6	14646	1686	8049	7482	6
	27 *a*	108	69	1233	1119	0	14754	1755	9282	8601	6
	28 *a*	87	69	774	1134	6	14841	1824	10056	9735	12
	29	228	66	816	1326	18	15069	1890	10872	11061	30
	30	138	12	570	972	12	15207	1902	11442	12033	42
	31	90	36	528	654	30	15297	1938	11970	12687	72

[a] *Partial interpolation for several hours of missed counts due to poor view conditions.*
[b] *Partial interpolation for several hours of missed counts during planned hiatus.*
[c] *interpolated count for the day.*
[d] *Counts are from right bank only from 6/28 - 7/22, 1994.*

Appendix 1B. Daily salmon counts from the Kulukak River tower,1995.

Date		1995 Daily Counts					1995 Cumulative Counts				
		Sockeye	Chinook	Chum	Pink	Coho	Sockeye	Chinook	Chum	Pink	Coho
June	18	0	0	0	0	0	0	0	0	0	0
	19	78	0	0	0	0	78	0	0	0	0
	20 *b*	120	0	0	0	0	198	0	0	0	0
	21	90	12	0	0	0	288	12	0	0	0
	22	78	30	12	0	0	366	42	12	0	0
	23	108	12	0	0	0	474	54	12	0	0
	24 *b*	66	12	6	0	0	540	66	18	0	0
	25 *b*	378	36	0	0	0	918	102	18	0	0
	26	426	30	0	6	0	1344	132	18	6	0
	27	192	48	0	0	0	1536	180	18	6	0
	28	438	24	0	0	0	1974	204	18	6	0
	29	564	30	12	18	0	2538	234	30	24	0
	30 *b*	675	12	0	0	0	3213	246	30	24	0
July	1	618	102	24	6	0	3831	348	54	30	0
	2	648	30	72	12	0	4479	378	126	42	0
	3	642	54	120	0	0	5121	432	246	42	0
	4	504	42	204	0	0	5625	474	450	42	0
	5	678	96	204	0	0	6303	570	654	42	0
	6 *b*	846	156	237	0	0	7149	726	891	42	0
	7	696	138	240	12	0	7845	864	1131	54	0
	8	660	42	60	0	0	8505	906	1191	54	0
	9	732	36	276	0	0	9237	942	1467	54	0
	10	972	42	510	6	0	10209	984	1977	60	0
	11	630	42	870	18	0	10839	1026	2847	78	0
	12	618	108	732	6	0	11457	1134	3579	84	0
	13	594	138	696	18	0	12051	1272	4275	102	0
	14	372	54	306	54	0	12423	1326	4581	156	0
	15	384	84	492	24	0	12807	1410	5073	180	0
	16 *b*	621	90	1125	42	0	13428	1500	6198	222	0
	17	390	162	930	66	0	13818	1662	7128	288	0
	18	288	114	798	48	0	14106	1776	7926	336	0
	19	504	132	1596	84	0	14610	1908	9522	420	0
	20	336	126	1038	72	0	14946	2034	10560	492	0
	21	180	66	534	18	0	15126	2100	11094	510	0
	22	210	18	480	54	0	15336	2118	11574	564	0
	23	144	24	528	18	0	15480	2142	12102	582	0
	24	218	41	566	23	0	15698	2183	12668	605	0
	25 *a*	95	47	365	26	0	15792	2229	13032	630	0
	26	48	48	312	36	0	15840	2277	13344	666	0
	27	72	66	756	132	0	15912	2343	14100	798	0
	28	18	60	138	96	0	15930	2403	14238	894	0
	29	6	0	108	9	0	15936	2403	14346	903	0
	30	18	12	96	42	0	15954	2415	14442	945	0
	31	6	0	30	6	0	15960	2415	14472	951	0
Aug	1	6	12	48	18	0	15966	2427	14520	969	0
	2	24	0	30	30	0	15990	2427	14550	999	0
	3	48	6	30	24	0	16038	2433	14580	1023	0

Appendix 1B. Continued.

Date		1995 Daily Counts					1995 Cumulative Counts				
		Sockeye	Chinook	Chum	Pink	Coho	Sockeye	Chinook	Chum	Pink	Coho
Aug 4	*b*	17	12	75	8	0	16055	2445	14655	1031	0
5	*c*	17	9	66	8	0	16071	2454	14721	1038	0
6		15	6	45	6	6	16086	2460	14766	1044	6
7		12	0	96	6	42	16098	2460	14862	1050	48
8		6	6	102	0	24	16104	2466	14964	1050	72
9	*b*	12	0	54	6	21	16116	2466	15018	1056	93
10		18	0	36	6	18	16134	2466	15054	1062	111
11	*b*	11	0	33	0	36	16145	2466	15087	1062	147
12	*c*	8	3	36	0	51	16152	2469	15123	1062	198
13		9	6	18	0	66	16161	2475	15141	1062	264
14	*b*	6	0	18	0	21	16167	2475	15159	1062	285
15		6	0	24	6	54	16173	2475	15183	1068	339
16	*b*	6	0	24	0	39	16179	2475	15207	1068	378
17		12	0	24	6	150	16191	2475	15231	1074	528
18	*b*	0	0	12	12	150	16191	2475	15243	1086	678
19	*c*	6	0	21	0	129	16197	2475	15264	1086	807
20		3	0	39	6	117	16200	2475	15303	1092	924
21	*b*	0	0	15	9	186	16200	2475	15318	1101	1110
22		6	6	6	6	228	16206	2481	15324	1107	1338
23	*b*	0	6	0	6	426	16206	2487	15324	1113	1764
24		0	0	12	0	180	16206	2487	15336	1113	1944
25	*b*	0	0	0	0	204	16206	2487	15336	1113	2148
26	*c*	0	0	3	0	243	16206	2487	15339	1113	2391
27		0	0	6	0	309	16206	2487	15345	1113	2700
28	*b*	0	0	0	6	435	16206	2487	15345	1119	3135
29		0	0	0	0	468	16206	2487	15345	1119	3603
30	*b*	0	0	0	24	510	16206	2487	15345	1143	4113
31		0	0	6	6	342	16206	2487	15351	1149	4455
Sept 1		0	0	0	12	492	16206	2487	15351	1161	4947
2	*c*	0	0	0	6	459	16206	2487	15351	1167	5406
3		0	0	0	0	285	16206	2487	15351	1167	5691
4	*b*	0	0	0	0	108	16206	2487	15351	1167	5799
5		0	0	0	0	168	16206	2487	15351	1167	5967
6	*b*	0	0	0	0	528	16206	2487	15351	1167	6495
7		0	0	0	0	1302	16206	2487	15351	1167	7797
8		0	0	0	0	414	16206	2487	15351	1167	8211
9	*b*	0	0	0	0	1800	16206	2487	15351	1167	10011
10		0	0	0	6	1422	16206	2487	15351	1173	11433
11	*b*	0	0	0	12	438	16206	2487	15351	1185	11871
12		0	0	0	0	720	16206	2487	15351	1185	12591
13	*b*	0	0	0	3	426	16206	2487	15351	1188	13017
14		0	0	0	6	486	16206	2487	15351	1194	13503

[a] *Partial interpolation for several hours of missed counts due to poor viewing conditions.*

[b] *Partial interpolation for several hours of missed counts during planned hiatus.*

[c] *interpolated count for the day.*

Appendix 1C. Daily salmon counts from the Kulukak River tower,1996.

Date			1996 Daily Counts					1996 Cumulative Counts				
			Sockeye	Chinook	Chum	Pink	Coho	Sockeye	Chinook	Chum	Pink	Coho
June	23		120	0	6	0	0	120	0	6	0	0
	24		102	0	0	0	0	222	0	6	0	0
	25		168	0	12	0	0	390	0	18	0	0
	26	*b*	348	0	12	36	0	738	0	30	36	0
	27		180	18	24	0	0	918	18	54	36	0
	28		330	24	36	0	0	1248	42	90	36	0
	29		384	0	78	0	0	1632	42	168	36	0
	30	*b*	1272	6	612	0	0	2904	48	780	36	0
July	1		594	12	570	36	0	3498	60	1350	72	0
	2		852	30	900	96	0	4350	90	2250	168	0
	3	*b*	642	24	1542	120	0	4992	114	3792	288	0
	4		540	12	1218	156	0	5532	126	5010	444	0
	5		828	18	1350	246	0	6360	144	6360	690	0
	6		996	12	954	144	0	7356	156	7314	834	0
	7	*b*	678	12	2034	306	0	8034	168	9348	1140	0
	8		696	36	1200	306	0	8730	204	10548	1446	0
	9		864	6	1068	354	0	9594	210	11616	1800	0
	10	*b*	792	72	1584	318	0	10386	282	13200	2118	0
	11		672	84	888	348	0	11058	366	14088	2466	0
	12		318	24	612	150	0	11376	390	14700	2616	0
	13	*b*	162	18	672	54	0	11538	408	15372	2670	0
	14		414	24	912	108	0	11952	432	16284	2778	0
	15		252	12	888	132	0	12204	444	17172	2910	0
	16		132	24	1230	138	0	12336	468	18402	3048	0
	17	*b*	240	24	864	102	0	12576	492	19266	3150	0
	18	*a*	228	30	1128	108	0	12804	522	20394	3258	0
	19	*a*	132	12	990	162	0	12936	534	21384	3420	6
	20	*b*	306	12	2118	390	0	13242	546	23502	3810	18
	21		192	12	1620	450	0	13434	558	25122	4260	18
	22		222	36	1308	678	0	13656	594	26430	4938	18
	23		270	84	966	678	0	13926	678	27396	5616	18
	24	*b*	102	48	552	288	0	14028	726	27948	5904	18
	25		30	36	606	486	0	14058	762	28554	6390	18
	26		24	54	540	252	0	14082	816	29094	6642	18
	27	*b*	42	30	474	120	0	14124	846	29568	6762	18
	28		24	42	636	294	0	14148	888	30204	7056	18
	29		18	0	426	222	0	14166	888	30630	7278	18
	30		12	6	348	126	0	14178	894	30978	7404	18
	31	*b*	102	6	396	234	0	14280	900	31374	7638	18
Aug	1		48	18	408	204	6	14328	918	31782	7842	24
	2		66	0	534	126	6	14394	918	32316	7968	30
	3	*b*	108	24	372	120	18	14502	942	32688	8088	48
	4		78	12	294	54	0	14580	954	32982	8142	48

Appendix 1C. Continued

Date			1996 Daily Counts					1996 Cumulative Counts				
			Sockeye	Chinook	Chum	Pink	Coho	Sockeye	Chinook	Chum	Pink	Coho
Aug	5		66	6	114	90	0	14646	960	33096	8232	48
	6		54	0	186	66	6	14700	960	33282	8298	54
	7	*b*	48	0	216	186	6	14748	960	33498	8484	60
	8		30	0	126	126	6	14778	960	33624	8610	66
	9	*b*	24	6	90	66	6	14802	966	33714	8676	72
	10	*b*	66	0	114	102	18	14868	966	33828	8778	90
	11		42	0	42	42	12	14910	966	33870	8820	102
	12		60	12	108	120	66	14970	978	33978	8940	168
	13		24	6	150	78	30	14994	984	34128	9018	198
	14	*b*	48	0	126	126	66	15042	984	34254	9144	264
	15		18	0	48	84	18	15060	984	34302	9228	282
	16		30	30	42	42	96	15090	1014	34344	9270	378
	17	*b*	48	6	48	42	96	15138	1020	34392	9312	474
	18		48	0	24	54	102	15186	1020	34416	9366	576
	19		30	0	6	96	1356	15216	1020	34422	9462	1932
	20		36	0	12	30	126	15252	1020	34434	9492	2058
	21	*b*	24	6	12	36	216	15276	1026	34446	9528	2274
	22		42	0	18	12	120	15318	1026	34464	9540	2394
	23		36	0	0	24	198	15354	1026	34464	9564	2592
	24	*b*	18	6	6	12	180	15372	1032	34470	9576	2772
	25		6	0	6	6	138	15378	1032	34476	9582	2910
	26		12	0	6	24	120	15390	1032	34482	9606	3030
	27		0	0	0	24	78	15390	1032	34482	9630	3108
	28	*b*	6	0	0	30	162	15396	1032	34482	9660	3270
	29		0	0	0	0	132	15396	1032	34482	9660	3402
	30	*b*	6	0	0	24	2460	15402	1032	34482	9684	5862
	31	*b*	6	0	0	12	1410	15408	1032	34482	9696	7272
Sept	1		0	0	0	0	318	15408	1032	34482	9696	7590
	2	*b*	0	0	0	18	216	15408	1032	34482	9714	7806
	3		0	0	0	12	252	15408	1032	34482	9726	8058
	4	*b*	0	0	0	12	246	15408	1032	34482	9738	8304
	5		0	0	0	12	198	15408	1032	34482	9750	8502
	6		0	0	0	18	786	15408	1032	34482	9768	9288
	7	*c*	0	0	0	12	576	15408	1032	34482	9780	9864
	8		0	0	0	0	366	15408	1032	34482	9780	10230
	9		0	0	0	0	174	15408	1032	34482	9780	10404

[a] *Partial interpolation for several hours of missed counts due to poor viewing conditions.*

[b] *Partial interpolation for several hours of missed counts during planned hiatus.*

[c] *interpolated count for the day.*

Appendix 2. Age, length, and sex composition of sockeye salmon sampled from the Kulukak River with a beach seine, 1994-1996.

	1994					1995					1996				
		Percent	Mid-Eye to Fork Length (mm)				Percent	Mid-Eye to Fork Length (mm)				Percent	Mid-Eye to Fork Length (mm)		
Age	N	Age	Mean	SE	Range	N	Age	Mean	SE	Range	N	Age	Mean	SE	Range
							Female								
0.2	5	3	502	11.9	455-520	--	--	--	--	--	4	2	505	24.2	435-540
0.3	27	18	525	3	495-560	4	2	530	5.4	520-545	44	25	539	2.8	505-595
1.2	18	12	489	6.5	440-525	50	29	496	4.7	420-555	6	3	517	9.5	475-545
0.4	--	--	--	--	--	3	2	545	7.6	535-560	--	--	--	--	--
1.3	95	65	533	2.3	480-625	102	58	536	2.5	455-590	118	66	552	2.1	485-610
2.2	1	1	--	--	485	4	2	493	7.8	480-515	1	1	--	--	510
	--	--	--	--	--	3	2	550	5.0	540-555	--	--	--	--	--
2.3	1	1	--	--	530	9	5	541	8.4	500-570	5	3	561	11.1	535-600
Total	147	100	524	2.2	440-625	175	100	523	2.5	420-590	178	100	547	1.8	435-610
							Male								
0.2	--	--	--	--	--	4	3	410	4.6	400-420	--	--	--	--	--
1.1	1	1	--	--	325	1	1	--	--	410	--	--	--	--	--
0.3	17	15	566	7	495-600	3	2	575	18.9	545-610	60	30	588	2.9	535-640
1.2	6	5	516	13.8	470-570	20	15	517	9.1	415-595	7	3	548	8.8	520-585
1.3	84	76	571	2.9	470-645	85	65	577	2.5	515-645	128	63	593	1.8	535-645
2.2	1	1	--	--	530	8	6	537	7.7	495-560	1	0	--	--	420
1.4	--	--	--	--	--	4	3	598	10.5	575-625	--	--	--	--	--
2.3	2	2	563	2.5	560-565	4	3	574	6.9	560-590	7	3	589	7.7	560-625
3.3	--	--	--	--	--	1	1	--	--	625	--	--	--	--	--
Total	110	100	564	3.5	325-645	130	100	560	4.0	400-645	203	100	589	1.8	420-645
							Both Sexes								
0.2	5	2	502	11.9	455-520	4	1	410	4.6	400-420	4	1	505	24.2	435-540
1.1	1	0	--	--	325	1	0	--	--	410	--	--	--	--	--
0.3	44	17	541	4.4	495-600	7	2	549	11.9	520-610	104	27	567	3.1	505-640
1.2	24	9	496	6.3	440-570	70	23	502	4.3	415-595	13	3	533	7.7	475-585
0.4	--	--	--	--	--	3	1	545	7.6	535-560	--	--	--	--	--
1.3	179	69	550	2.3	470-645	187	61	555	2.3	455-645	246	65	574	1.9	485-645
2.2	2	1	508	22.5	485-530	12	4	522	8.4	480-560	2	1	465	45.0	420-510
1.4	--	--	--	--	--	7	2	577	11.3	540-625	--	--	--	--	--
2.3	3	1	552	10.9	530-565	13	4	551	7.4	500-590	12	3	577	7.4	535-625
3.3	--	--	--	--	--	1	0	--	--	625	--	--	--	--	--
Total	258	100	542	2.3	325-645	305	100	539	2	400-645	381	100	569	1.7	420-645

Appendix 3. Age, length, and sex composition of chinook salmon sampled from the Kulukak River using a beach seine and hook and line gear, 1995 and 1996.

	1995					1996				
		Percent	Mid-Eye to Fork Length (mm)				Percent	Mid-Eye to Fork Length (mm)		
Age	N	Age	Mean	SE	Range	N	Age	Mean	SE	Range
Female										
1.2	3	10	618	18.0	585-645	2	29	560	0.0	560
1.3	8	28	741	20.0	690-855	1	14	--	--	813
1.4	17	59	860	16.0	720-960	4	57	850	18.6	800-885
1.5	1	3	--	--	910	--	--	--	--	--
Total	29	100	804		585-960	7	100	762	53.2	560-885
Male										
0.2	1	4	--	--	460	--	--	--	--	--
1.1	1	4	--	--	375	3	50	390	10.0	380-410
1.2	13	50	537	13.0	465-635	--	--	--	--	--
1.3	1	4	--	--	660	2	33	715	5.0	710-720
1.4	8	31	956	27.0	820-1050	1	17	--	--	760
1.5	2	8	1003	12.0	990-1015	--	--	--	--	--
Total	26	100	697		375-1050	6	100	560	76.5	380-760
Both Sexes										
0.2	1	2	--	--	460	--	--	--	--	--
1.1	1	2	--	--	375	3	23	390	10.0	380-410
1.2	16	29	552	14.0	465-645	2	15	560	0.0	560
1.3	9	16	732	20.0	660-855	3	23	748	32.8	710-813
1.4	25	45	891	16.0	720-1050	5	38	832	23.0	760-885
1.5	3	5	972	32.0	910-1015	--	--	--	--	--
Total	55	100	754	179.0	375-1050	13	100	669	52.2	380-885

Appendix 4. Age, length, and sex composition of chum salmon sampled from the Kulukak River with a beach seine, 1994-1996.

	1994					1995					1996				
		Percent	Mid-Eye to Fork Length (mm)				Percent	Mid-Eye to Fork Length (mm)				Percent	Mid-Eye to Fork Length (mm)		
Age	N	Age	Mean	SE	Range	N	Age	Mean	SE	Range	N	Age	Mean	SE	Range
								Female							
0.2	--	--	--	--	--	6	3	544	6.1	525-570	--	--	--	--	--
0.3	83	48	548	2.8	490-620	57	32	565	3.8	485-635	148	76	590	2.1	530-665
0.4	83	48	557	3	505-665	104	58	580	2.5	530-645	42	21	601	3.1	545-645
0.5	8	5	572	6.6	540-595	13	7	595	6.6	570-650	6	3	601	7.8	580-630
Total	174	100	553	2	490-665	180	100	575	2.1	485-650	196	100	593	1.8	530-665
								Male							
0.2	--	--	--	--	--	6	2	575	12.8	535-625	--	--	--	--	--
0.3	47	30	590	4.6	505-606	80	30	592	3.3	515-655	312	80	625	1.7	560-755
0.4	85	54	598	3.2	535-675	151	57	615	2.4	550-710	68	17	643	3.4	585-720
0.5	25	16	603	7.3	505-670	28	11	620	5.9	520-670	10	3	645	9.8	585-685
Total	157	100	596	2.5	505-675	265	100	608	1.9	515-710	390	100	629	1.5	560-755
								Both Sexes							
0.2	--	--	--	--	--	12	3	560	8.2	525-625	--	--	--	--	--
0.3	130	39	563	3	490-660	137	31	581	2.8	485-655	460	78	614	1.5	530-755
0.4	168	51	577	2.7	505-675	255	57	600	2	530-710	110	19	627	3.1	545-720
0.5	33	10	596	6.2	505-670	41	9	612	4.9	520-670	16	3	629	8.7	580-685
Total	331	100	573	2	490-675	445	100	594	1.6	485-710	586	100	617	1.4	530-755

Appendix 5. Age, length, and sex composition of coho salmon sampled from the Kulukak River using a beach seine and hook and line gear, 1995 and 1996.

	1995					1996				
		Percent	Mid-Eye to Fork Length (mm)				Percent	Mid-Eye to Fork Length (mm)		
Age	N	Age	Mean	SE	Range	N	Age	Mean	SE	Range
					Female					
1.1	33	18	575	6.8	420-635	26	23	600	6.7	530-675
2.1	136	76	583	2.8	475-645	87	77	614	4.9	475-680
3.1	10	6	591	11.6	525-640	--	--	--	--	--
Total	179	100	582	2.5	420-645	113	100	611	4.1	475-680
					Male					
1.1	37	21	552	8.8	455-645	23	20	620	8.9	525-675
2.1	135	77	577	4	450-695	90	79	613	5.6	445-715
3.1	3	2	585	45.4	530-675	1	1	--	--	685
Total	175	100	572	3.7	450-695	114	100	615	4.8	445-715
					Both Sexes					
1.1	70	20	563	5.8	420-645	49	22	609	5.6	525-675
2.1	271	77	580	2.4	450-695	177	78	613	3.7	445-715
3.1	13	4	589	12.5	525-675	1	<1	--	--	685
Total	354	100	577	2.3	420-695	227	100	613	3.1	445-715

Appendix 6. Results from two-tailed t-test comparing lengths between male and female salmon sampled from the Kulukak River, 1994-1996.

Species	Year	Age	*t*	df	*P*	Significantly Larger
Sockeye	1994	0.3	6.2	42	<0.001	male
		1.2	1.96	22	0.062	----
		1.3	10.6	177	<0.001	male
		all	10.1	256	<0.001	male
	1995	0.3	2.6	5	0.046	male
		1.2	2.3	68	0.027	male
		1.3	11.8	185	<0.001	male
		1.4	3.6	5	0.015	male
		2.2	3.6	10	0.005	male
		2.3	2.4	11	0.036	male
		all	7.98	303	<0.001	male
	1996	0.3	11.6	102	<0.001	male
		1.2	2.4	11	0.036	male
		1.3	14.96	244	<0.001	male
		2.3	2.1	10	0.060	----
		all	16.4	379	<0.001	male
Chum	1994	0.3	8.19	329	<0.001	male
		0.4	9.38	128	<0.001	male
		0.5	2.32	166	0.030	male
		all	13.46	31	<0.001	male
	1995	0.2	2.17	10	0.060	----
		0.3	5.51	135	<0.001	male
		0.4	9.97	253	<0.001	male
		0.5	2.51	39	0.020	male
		all	11.26	443	<0.001	male
	1996	0.3	12.38	458	<0.001	male
		0.4	8.52	108	<0.001	male
		0.5	3.16	14	0.007	male
		all	14.46	584	<0.001	male
Coho	1995	1.1	-2.1	68	0.040	female
		2.1	-1.2	269	0.231	----
		3.1	-0.18	11	0.862	----
		all	-2.25	352	0.025	female
	1996	1.1	1.83	47	0.070	----
		2.1	-0.16	175	0.880	----
		all	0.65	225	0.520	----
Chinook	1995	1.2	-2.7	14	0.016	female
		1.4	3.3	23	0.003	male
		all	-2.3	53	0.026	female
	1996	all	-2.2	11	0.049	male